SteamGrounds: a real-time strategy game for a multitouch table with fiduciary markers

Luciano H. O. Santos

Marcus V. Lamar

Carla D. Castanho

Department of Computer Science University of Brasília Brasília – Brazil

Abstract

We present a tower defense real-time strategy game, named *Steam-Grounds*, which employs gestures performed over a multitouch table and fiduciary markers as input mechanisms. It provides a natural and intuitive gameplay through the association of the markers to game elements that can be directly manipulated by players. A low cost multitouch table was also designed and built. We adopted a hybrid infrared illumination approach, with both FTIR and DI, allowing simultaneous recognition of touches and fiduciary markers.

Keywords:: multitouch table, RTS game, fiduciary markers

Author's Contact:

{lamar,carlacastanho}@cic.unb.br lucianosantos@thebalanceinc.com

1 Introduction

The evolution of hardware and software components enabled systems to process more complex input elements and fostered the design of elaborate user interfaces. Several works have studied usermachine interaction possibilities, aiming to make them more intuitive. Recent examples include multitouch displays, motion sensing devices and body movement based interfaces. Commands based on habitual and intrinsic actions are more natural to humans, including speech and gestures, as well as interaction with everyday objects that can be touched and handled [Rauterberg and Steiger 1996]. For this reason, studies on natural interfaces seek ways to recognize typical human actions and translate them into commands for the computer.

In the context of digital games, the search for natural and intuitive input mechanisms has become imperative, since this kind of software takes huge advantage of new interaction paradigms. The application of Tangible User Interfaces (TUIs) [Ishii and Ullmer 1997] concepts in game interaction has significantly enriched the gameplay. Devices with multitouch displays, for example, are growing more popular every day because of the intuitive experience they provide. Many games have been specially designed for this kind of device. The mobile market has several successful examples, developed to suit the new smartphones and tablets. Due to size limitations, however, such devices typically offer an individual experience. Multitouch tables on the other hand, offer similar interaction possibilities with the advantage of having a physical structure that stimulates face-to-face group interaction, an essential aspect in several kinds of games [Kirton, T. et al 2008].

Furthermore, as an attempt to bridge the gap between PC-based paradigm and innovative gaming environments, such as multitouch tables, fiduciary markers have been introduced as a mechanism for physical objects detection [Bencina, R. et al 2005][Kaltenbrunner, M. et al 2006a]. Fiducials are specially designed markers that can be attached to a physical object to track its position and rotation.

Games of the Real Time Strategy (RTS) genre may take special advantage of a gaming environment that allows natural input mechanisms. RTS games typically require the control of a large number of units and resources. The gameplay experience may be significantly enhanced if the player can easily give orders and organize the game elements by means of a direct, friendly and natural interface such as a multitouch table. Tower Defense (TD) games, a subgenre of RTS in which the player must place shooting towers in a map to avoid the passage of the enemies, is even more suited to the interface of a multitouch table that recognizes real objects with fiduciary markers, as they can be directly associated to the towers. In this work, we have designed and implemented a tower defense

game, named SteamGrounds, for a multitouch table with fiduciary markers. In this implementation the markers represent the towers placed by the players on the tabletop where the game map is displayed. This project also involved the design and construction of the multitouch table which uses a projector to display the images on the surface and a camera to capture user interactions. Our table uses the hybrid illumination approach [Luderschmidt and Dörner 2008], employing both, FTIR (Frustrated Total Internal Reflection) [Han 2005] and DI (Diffuse Illumination) [Schöening, J. et al 2009], which allow efficient finger and fiducials detection, respectively.

The remaining of this paper is organized as follows. Next section describes some related works. Then, we present SteamGrounds' game concept, some of its implementation details and the multitouch table's structure. Finally, we give some concluding remarks and future works.

2 Related Work

IRTaktiks is a real-time strategy game for a multitouch table designed for two players [Schneider, W. et al 2008]. Each player has a set of customizable units, controlled by touches. Although the commands may be given concurrently by the players, each player controls a different area of the map, which is divides in two sections. The game identifies each player according to the region of the map they have touched. The construction of the table, also part of the project, was based on the FTIR (Frustrated Total Internal Reflection) illumination method. Another example of a game developed for a multitouch table with a similar illumination approach is the Asterocks [Wolfe, C. and Smith, J. and Graham, T. 2008].

In [Brandão et al. 2009], the authors present a multiplayer tower defense game, named EcoDefense, designed and constructed for a multitouch table. Its theme is based on environmental issues. Basically, the players must avoid clouds of smoke generated by a central factory from reaching a forest located on the borders of the map. To do so, players should touch the moving clouds in order to destroy them before they damage the forest. Auxiliary towers can be build and positioned in the map as the game evolves. EcoDefense promotes team work as all players have a unique goal. The multitouch table constructed in this project was based only DI (Diffuse Illumination) method.

Although not designed for game purposes, the reacTable [Kaltenbrunner, M. et al 2006a] is probably the currently best known multitouch table.Developed in the Universitat Pompeu Fabra (Barcelona) it is a table based musical instrument that combines tangible input (movement of tagged objects on a flat surface) with multitouch interaction on the surface. The objects are labeled with fiduciary markers which are associated with virtual elements that can generate, modify or control sound. The objects, pucks in this case, can be placed on the surface, rotated and connected by the user to experiment with sounds and create unique music. The same project also created the framework reacTIVision [Bencina, R. et al 2005], which applies image processing to detect markers, and the TUIO protocol [Kaltenbrunner, M. et al 2006b], which defines the format of the messages exchanged between the framework and client applications. The reacTable employs DI (Diffuse Illumination) method.

Based on the reacTable, a similar device, named Bricktable was constructed [Hochenbaum and Vallis 2009]. It also uses the reac-TIVision framework and DI approach for illumination. Among the applications developed for the Bricktable is the Weather Report, a sonification instrument. Basically, the application receives the United States weather forecast and displays its map with the current temperature in each area. The temperature of the area in which the objects are placed changes the sounds generated, thus users can move tangible objects around the surface in order to trigger and compose different sounds.

An hybrid illumination approach, which attempts to obtain the benefits of both, DI and FTIR, was employed by the Virttable [Luderschmidt and Dörner 2008]. An interactive application, named Vispol, was developed for testing purposes. It aimed to help the police of the state of Hesse (Germany) to visualize connections between persons and objects that are involved in special operations.

3 SteamGrounds

SteamGrounds is a tower defense game that targets a multitouch table with fiduciary markers. The game explores the interactivity of the table providing an intuitive and natural interface for this genre of games.

3.1 Game Concept

As a typical tower defense genre game, SteamGrounds, in each of its stages, defines a region of the screen from which the enemies depart, and another one they must reach. The player loses if the number of enemies that arrive safely to the destination exceeds a certain limit. To avoid this, the player has at his/her disposal a set of towers that may be placed in the map to defend the destination point. Each kind of tower is represented by a different fiduciary marker, which is a square piece of acrylic with a symbol on the bottom (Figure 1). Each tower created by the player is associated to its marker allowing the player to manipulate it.



Figure 1: The fiduciary markers.

The towers are the only entities that can attack while the enemies are controlled by the computer and try to achieve their goal by the shortest path possible. By default, a tower will automatically attack the enemies within its range. The player must always leave at least one free path so enemies can go through. In order to win, he/she cannot simply block the enemies' way, but instead should focus on strategy and resource management skills.

Players can acquire new towers and upgrade existing ones. The fiduciary markers make the experience of tower creation and manipulation more intuitive. When a certain marker is positioned over the table, the game identifies it and, if possible, creates a new tower in that position. This tower is then associated to the marker for the rest of the game, and the player may move it in order to move the tower. When a marker is removed from the table or moved to an invalid position, it is considered that the respective tower was sold. The player may touch the surface near a tower to visualize its properties, such as current status and upgrade options.



Figure 2: The gestures used in SteamGrounds.

Some special towers do not attack enemies automatically, but are triggered in response to gestures performed by the player. Such towers have longer reload times, but offer more powerful and broad attacks. Each type of special tower is activated by a specific gesture (Figure 2), that must be performed close to it and also determines the direction of the attack.

The game was designed to be played by several people simultaneously, taking advantage of the table layout which promotes group interaction. All the resources are shared and there is no distinction between players, therefore requiring strategies to be decided by the whole group in common agreement. To support this group interaction, the HUD (Head-up Display) is replicated on each side of the table, correctly oriented to be read by the correspondent players, as illustrated in Figure 3. It contains information such as the number of enemies that reached destination so far, the type of the next wave of enemies, the current amount of money available and the types of towers allowed in the current stage. The icons and buttons in the HUD may be directly touched by the user.



Figure 3: Screenshot of the SteamGrounds game.

The objective of SteamGrounds is to win all the stages, as they increase in difficulty and complexity. The player must adapt to the new challenges imposed by the changes in terrain, strength and power of the enemies, and resources availability. He/she must learn when and how to make use of the new available towers, as well as evaluate the cost-benefit of their types and upgrades. Planning the enemies path through a strategic placement of towers can maximize the damage and the number of enemies killed.

Figure 4 shows the SteamGrounds game being executed in the constructed table.



Figure 4: SteamGrounds in execution.

3.2 Implementation

The software architecture of the game was divided in engine and specific code layers [Rabin 2005]. The game engine was developed with a set of open source libraries to control graphics, audio and input. For video initialization, image and text loading, and input, the SDL (Simple Direct-media Layer) [Lantinga 2011] was used. For graphics in general, OpenGL (Open Graphics Library) [Khronos Group 2011] and OpenAL (Open Audio Libray) [Creative Technology 2011] for audio.

The multitouch input was captured with TuioClient [Kaltenbrunner, M. et al 2010], a library to receive TUIO (Tangible User Interface System) protocol messages [Kaltenbrunner, M. et al 2006b]. This protocol was developed specifically to deliver messages about the status of objects in tangible surfaces, and was first used with the reacTable, described in Section 2. The CCV (*Community Core Vision*) [NUI Group Community 2011] is a framework, based on OpenCV (Open Computer Vision) library [Intel 2010], for finger and fiduciary markers recognition. The framework acts as a TUIO server, sending messages, about the fingers and markers on the surface, that are captured by the game through TuioClient.

4 The Multitouch Table

The table built for SteamGrounds game was based on the multitouch device proposed by Luderschmidt [Luderschmidt and Dörner 2008]. Our design employed a combination of a projector, a camera and a computer to create a tangible surface system. The projector displays the image at the table top, which is an acrylic plaque, with a translucent sheet of paper attached to its bottom. The camera is connected to the computer and captures the image of the surface, from below, so the system can detect fingers and markers by means of image processing. The general structure is shown in Figure 5.



Figure 5: Side view of the table.

Detection of fingers and markers over the surface is accomplished with the use of infrared light and application of filters, in a way that the regions of interaction are highlighted and patterns can be recognized. The camera, a Sony PSEye [Sony 2011] with resolution of 640x480 pixels and a 60 Hz maximum frame rate, was

XI SBGames - Brasília - DF - Brazil, November 2nd - 4th, 2012

Computing Track - Short Papers

adapted to capture infrared light only. This was done by removing the infrared blocking filter and adding an infrared only pass filter.

The lighting system is designed to illuminate the surface in a way that highlights the regions where interaction occurs. Infrared light is used to avoid the noise of visible light in the environment. The most basic system, called DI (Diffuse Illumination) [Schöening, J. et al 2009], relies on the homogeneous, translucent layer between the surface and the light source to scatter the light throughout the surface. When a solid or reflective element is put over it, the light is reflected and forms a brighter region, as shown in Figure 6(a).

Another technique that brings more precise detections is FTIR (Frustated Total Internal Reflection) [Han 2005], which employs the optical phenomenon of total internal reflection of light to create the contrast on the surface. The principle consists of making the source emit infrared light directly inside the acrylic pane, which has a high refractive index, causing the light to be trapped inside the material by total internal reflection. When fingers interact with the surface, the total internal reflection is interrupted and a bright spot forms as illustrated in Figure 6(b).

Although FTIR is more effective than DI to detect touches, as the contrast generated is higher and the noise lower, it is not suitable to detect markers [Muller 2008]. The physical objects that act as markers typically do not make a close contact with the surface as the human finger does. Therefore, the desired interruption effect is not achieved. To solve this problem, the hybrid illumination system presented in [Luderschmidt and Dörner 2008] was adopted for this project. This system benefits from both techniques, that is, the accuracy of FTIR to detect finger touches and the ability of DI to detect markers.







(b) FTIR [Han 2010]

Figure 6: Lighting systems.

We used the CCV to pre-process the image and segment only the regions of interaction. The filters applied in the pre-processing stage enhance the contrast and segment the regions of interest resulting in a final image where each pixel is turned into black or white, indicating non-interaction and interaction, respectively. The final image is obtained through background removal, noise reduction, and finally, a threshold based on the intensity. Figure 7 illustrates these steps and the final image.



(c) noise reduction

(d) threshold

Figure 7: Pre-processing of the image.

The detection stage segments fingers and markers patterns from the final image. Both detections need to recognize regions of pixels with same intensity. While fingers are easily detected by its oval form, CCV uses a more complex topological algorithm to detect and classify markers, as described in [Bencina, R. et al 2005]. Once the elements are detected, CCV creates TUIO messages and sends them to any listening clients.

5 Conclusions

This work contributed to the realization of TUIs concepts in the context of electronic games. It explored the use of a natural and intuitive interface to improve player experience in a collaborative gaming environment. More precisely, we developed a real-time strategy tower defense game, named SteamGrounds, targeted to a multitouch table which recognizes fiduciary markers and gestures over its surface. The gameplay was enhanced through the association of the markers to game elements that can be directly manipulated by players.

The construction of the multitouch table was also part of this project. In order to efficiently meet the requirements of the Steam-Grounds game, we adopted a hybrid illumination approach, using both FTIR and DI. Thus, simultaneous recognition of touches and fiduciary markers could be accomplished.

As future works, the fiduciary markers may be redesigned to smaller sizes so the elements in the screen are more visible, and may also take different shapes to ease the identification by the player. The game may be expanded in units, enemies, stages, and new types of gestures. New applications and games can be designed to explore the characteristics of our table.

References

- BENCINA, R. ET AL. 2005. Improved Topological Fiducial Tracking in the reacTIVision System. In *Proc. CVPR 2005*, IEEE, 99–106.
- BRANDÃO, P., BRAGA, S., CASTANHO, C., AND JACOBI, R. 2009. Construção de um jogo multiusuário para uma superfície de projeção multitoque. In *Proc. SBGames 2009*, SBC.
- CREATIVE TECHNOLOGY, 2011. OpenAL Open Audio Library. http://connect.creativelabs.com/openal/default.aspx, June.

- HAN, J. 2005. Low-cost multi-touch sensing through frustrated total internal reflection. In *Proc. UIST 2005*, ACM, 115–118.
- HAN, J. Y., 2010. Multi-Touch Interaction Research. http://cs.nyu.edu/jhan/ftirtouch/, June.
- HOCHENBAUM, J., AND VALLIS, O. 2009. Bricktable: A Musical Tangible Multi-Touch Interface. In 2009 Berlin-Open Conf.
- INTEL, 2010. OpenCV Open Source Computer Vision. http://opencv.willowgarage.com/, June.
- ISHII, H., AND ULLMER, B. 1997. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proc. CHI* 1997, ACM, 234–241.
- KALTENBRUNNER, M. ET AL. 2006. The reacTable: A Collaborative Musical Instrument. In *Proc. WETICE 2006*.
- KALTENBRUNNER, M. ET AL. 2006. TUIO: A protocol for tabletop tangible user interfaces. In *Proc. GW 2006*.
- KALTENBRUNNER, M. ET AL, 2010. TUIO.org. http://www.tuio.org/, December.
- KHRONOS GROUP, 2011. OpenGL Open Graphics Library. http://www.opengl.org/, June.
- KIRTON, T. ET AL. 2008. PINS : A Prototype Model Towards the Definition of Surface Games. *Proc. MM 2008*.
- LANTINGA, S., 2011. Simple DirectMedia Layer. http://www.libsdl.org/, June.
- LUDERSCHMIDT, J., AND DÖRNER, R. 2008. Conception, Realization and Evaluation of Multi-touch Interfaces for Interactive Visualizations. Wiesbaden University of Applied Sciences, Germany.
- MULLER, L., 2008. Multi-touch displays: design, applications and performance evaluation. Master Thesis.
- NUI GROUP COMMUNITY, 2010. NUI Group Natural User Interface Group. http://nuigroup.com/, June.
- NUI GROUP COMMUNITY, 2011. Community Core Vision. http://ccv.nuigroup.com/, March.
- RABIN, S. 2005. Introduction To Game Development (Game Development). Charles River Media, Inc., Rockland, MA, USA.
- RAUTERBERG, M., AND STEIGER, P. 1996. Pattern Recognition as a Key Technology for the Next Generation of User Interfaces. In *Proc. SMC 1996*, IEEE, 2805–2810.
- SCHNEIDER, W. ET AL. 2008. IRTaktiks: Jogo de Estratégia para Mesa Multitoque. In *Proc. SBGames 2008*, SBC.
- SCHÖENING, J. ET AL. 2009. Building Interactive Multi-Touch Surfaces. Journal of Graphics, GPU, and Game Tools 14, 3, 35–55.

SONY, 2011. PlayStation Eye. http://www.sony.com/, July.

WOLFE, C. AND SMITH, J. AND GRAHAM, T. 2008. A low-cost infrastructure for tabletop games. In *Proc. of the Conf. on Future Play: Research, Play, Share*, ACM, 145–151.